ULSAN NATIONAL INSTITUTE OF SCIENCE AND TECHNOLOGY

Two-dimensional analysis for implementing nondestructive crack detection system in automotive production line

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Major Advisor

Franklin Bien

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Abstract

According to the automotive market trend, the vehicle machine needs to the electronic com ponents. In the automotive body panel, appearance of cracks is one of the most serious chall enge. Sometimes surface cracking will cause an unexpired expenses in production process. Th e most common method used to detect the crack in automotive press line is a visual scannin g of objects, parts or components which is the oldest and reliable non-destructive testing met hod. This test method is applied to almost every automotive product as a quality assurance.

However, the specific optimization method with great accuracy the time and effort is requir ed for high speed throughput in an automated press line system. An acoustic emission is a te chnique which centered on the concept of utilizing the transducer action of a flaw in a stress field. This technique was used to investigate fatigue crack characteristics such as initiation clo sure and propagation on smooth specimens. It is shown that acoustic emission from unflawed tensile specimens can be treated from a dislocation dynamics approach. The choice of analytic al method is extremely important and should not only focus on high-accuracy crack detection, but should also low-cost with high-efficiency in this system. In cases where crack is expected or necessary, the analytical method should detect the acoustic emission signal while the accur acy of the resulting measurements should fall within an acceptable range. The purpose of the detection system is acquisition correctly and to verify accuracy of the measurements. When th e accuracy of crack detection falls out of predetermined acceptability criteria, usually within 2 0% accuracy, the measured data should be reanalyzed by using other methods, if necessary. T he system consists of two parts: the hardware and the DSP (digital signal processing) part w hich includes AE parameter analyzer, based on the LabVIEW program. The crack acquisition system is set to sampling rate of 300 KHz with 20dB pre–amplification. As a result, maximu m received frequency range is 150 kHz according to the field test. Operating temperature is -40˚C ~ +85˚C considering the severe press factory environment with 7 seconds to analyze the data. The proposed system was tested and successfully demonstrated crack detection in an act ual automotive production line.

Contents

List of Figures

List of Tables

Chapter I

Introduction

Due to the classical method's strong limitations when crack occurred in automotive product line, the novel method for predicting fatigue crack is urgently needed. In this paper, the nondestructive crack detection system in press panel using acoustic emission parameters for automotive press panels is presented. The analysis and monitoring of the tensile impact test signal are of the concern for crack detection and implementing predictive maintenance. Experiments and analyses are conducted with several kinds of the acoustic emission technique. Two-dimensional analysis using duration parameter provides a strategy for detecting crack panel specimens from measured data. The tensile impact test fully demonstrates the proposed technique and the analysis method can be effectively applied to the process design for crack scanning system in automotive product line with a low error rate. The purpose of this system is improve detection ability of crack during an ongoing process which operates seven times a minute.

1.1. Cracks in automotive press panel

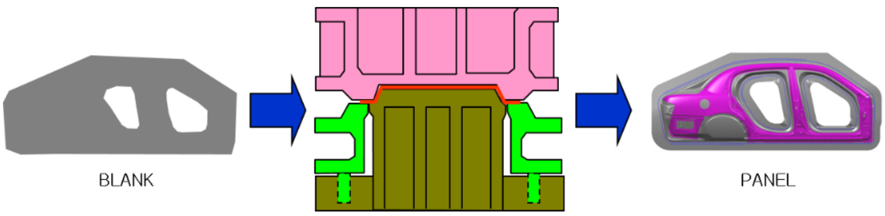


Figure 1-1: Automotive press panel.

To raise the competitiveness in the global market, a company should encourage the development of the domestic market. In a world that will only continue to become more complex, an automotive company has to consider innovative ways to improve their production standards. Maintaining a high build quality is one of the major challenges. It not only poses as serious challenge to production quality, but also, production time and production costs. One of the several manufacturing challenges is appearance of cracks in the automobile body and components.

The cracks occur due to elevated local stresses and result in an inferior build quality. Visual inspection is the method normally employed for crack detection, in which automotive press panels are checked using the naked eye. However, this has been a problem for automotive manufacturing companies because it raises productivity issues due to its worker dependence. It can also cause an accuracy issue because the visual inspection of press panels uses a forecasting model. Thus, a new method is needed.

Figure 1-2: Cracks in automotive press panel.

1.2. Thesis Contribution

This thesis focuses on the aspects of nondestructive testing method for crack detection which can be easily applied to automotive production line.

- Nondestructive crack detection system: The cost damage caused by the all inspection has been taken worse recently in the automotive industry. In this paper, a real-time crack detection system with AE method which specially produced for automotive industry is demonstrated. The main purpose of this system is correctly detecting a crack during an ongoing process. The system consisted of two parts: the hardware and digital signal processing (DSP) part. A laboratory measurement was employed for simulation. The crack occurrence tendency was measured using a data acquisition system. This research found a promising technique for improving a crack detection system based on experimental results, which showed that the duration of the AE parameters had a high probability of success.

Chapter II

Technical Challenges

This chapter demonstrates the challenges of nondestructive testing method for crack detection system in automotive press line, and the technical approaches to solve those issues are discussed. Finally, the requirements to implement crack detection system are stated.

2.1 Current status

The non-destructive detection and evaluation of the cracks are highly desirable from the view point of safe and economic operation of installed facilities such as power stations, industrial plants and pipe lines. The fatigue cracks or other pre-existing cracks could lead to sudden, sometimes catastrophic, failure of structural components. On an automotive press manufacturing line, the classical detection method has some limitations. The most common limitation is its difficulty in perfectly detecting every crack in a real manufacturing environment due to its dependence of workers.

Evaluation of the crack area and detection of the crack are critically important for some components that are subjected to cyclic stress. Magnetic techniques have been shown to be useful for crack detection in ferromagnetic materials and to be sensitive to the microstructural changes induced by cyclic stress. When the crack is formed, the quantity evaluation of crack area or crack length is important in order to estimate fatigue damage or to study the propagation of fatigue cracks. Several non-destructive test (NDT) techniques have been developed to capturing cracked regions in the material. These techniques are named as radiographic methods, ultrasound methods, thermographic methods, and Eddy current techniques. In this paper, an advanced method is presented that applies the AE detection method to find cracks in automotive press panel manufacturing.

2.2 Various approaches to crack detection

2.2.1 Destructive testing method

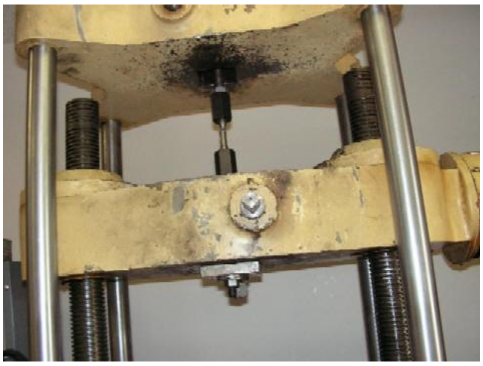


Figure 2-1: Destructive testing method.

The destructive testing method are defined as detect the object by using direct measurement for obtain the target's information such as chemical composition, dimensional geometry. Even it supply the reliability to the user due to its detecting method, the only limitation here is its inspection method. Since it needs to break the object, this method is not suitable for the crack detection system in automotive press panel.

2.2.2 Nondestructive testing method

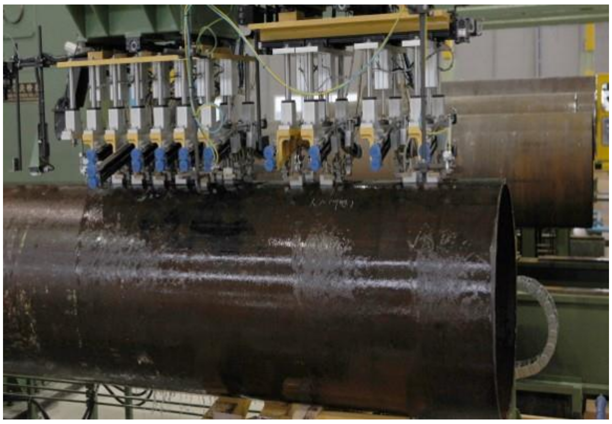


Figure 2-2: Nondestructive testing method.

The non-destructive testing is the opposite of destructive testing method. It employed non-destructive continuous monitoring method in crash detection system. This method is relative measurement technique in crack detection system. This method could be preserved the object without any destructive manner due to its measurement method.

2.2.2.1 Eddy current Testing (ET)

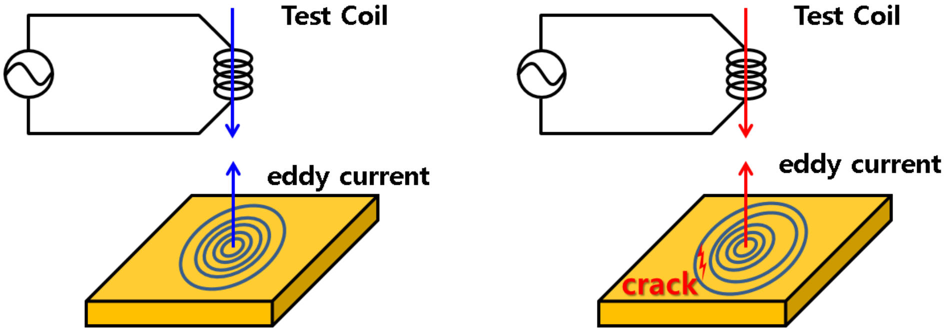


Figure 2-3: Eddy current Testing.

The eddy current testing is another candidate for crack detection method in this system. According to the Faraday's law, the eddy current will change when the crack occurred. Due to this change, the impedance of AC source's circuit will be changed. By inspection of this change value, the user can detect the crack occurrence. Even though this method is non-contact measurement which is suitable for the detection system of automotive production line, this method has demerits. Since it cannot penetrate the heave material that means this method is not appropriate candidate of the crack detection system in automotive press panel.

2.2.2.2 Ultrasonic Testing (UT)

Figure 2-4: Ultrasonic Testing.

The Ultrasonic testing employed the transducer for detection and extraction the target's information. During the detection period, this transducer will transmit the specialized signal to the object for getting the information. By comparing the received signal from the target, this method can distinguish the particular situation such as crack occurrence situation in automotive press panel. This system is used for internal defect detection, however, it needs to skilled operator due to its complex and unexpected disturbance. Since it also cannot detect the heavy material inspection, this method also not suitable for the crack detection system in automotive press panel.

2.2.2.3 Acoustic Emission Testing (AET)

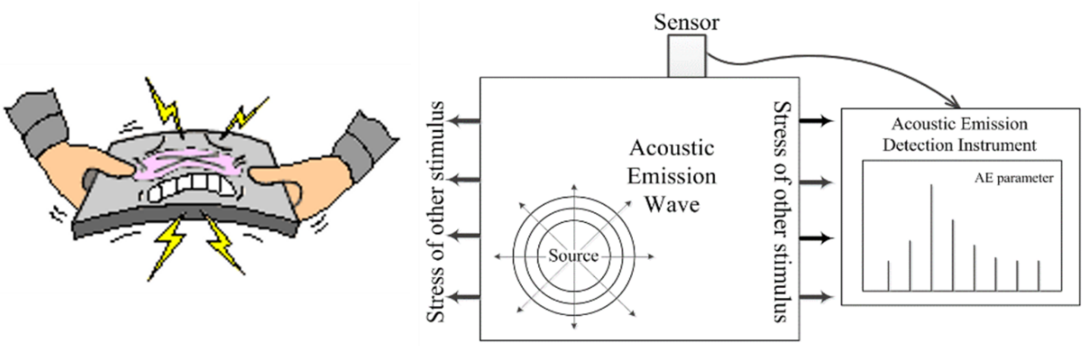


Figure 2-5: Acoustic Emission Testing.

AEs (Acoustic emissions) are transient elastic waves generated by the rapid release of the energy from localized sources, which could be cracks, corrosion, delamination, etc. Defects or flaws generate acoustic emissions or low frequency ultra sounds by themselves under variable stresses. An AE wave can propagate in all directions inside the material and can be detected by AE sensors installed some distance away from the AE source. The productivity could be increased by using an AE detection method because automated equipment can be substituted for workers. This will bring many benefits to users such as real time analysis and the ability to minimize the rework costs by preventing a faulty press on the line.

When a solid material is stressed, imperfections within the material emit short bursts of acoustic energy called "emissions." Such AEs can be detected by special receivers. An emission source can be evaluated through the study of its intensity and arrival time to collect information such as the location of the energy source. A crack that occurs in an automotive press panel can be detected using this NDT method.

In an automotive press line, automation equipment is used to improve the productivity. However, some kinds of facilities have a potential for error related to their long operating times. Since increasing temperature produced by this continuous work brings about molding pressure changes, it can result in the occurrence of cracks in the press panel. Depending on the level of fracture, there are three kinds of cracks: the breakage, neck, and crack. First, breakage represents damage from a relatively large scale crack. A neck is slight damage that occurs from a crack due to some error factors. A crack, which is the detection target of this paper, represents damage that falls between a breakage and neck. This kinds of crack happens most of the times in a press line and is difficult to find with a detection system compared to a breakage. It supplies continuous monitoring opportunities to the user.

Chapter III

Proposed Approach

The system consists of two parts: acoustic signal sensing device and digital signal processing using labview. Acoustic emission technique was applied to determine when a microcrack initiated on the specimens in tensile impact test. The threshold stress intensity ranges were determined by combining Acoustic emission tests. Several published formulae for crack-opening stress were examined.

3.1 Crack detection system using AET in automotive panel

Nondestructive testing	Strong point	Weak point
Eddy Current	Non-contact measurement	Heavy material inspection
Ultrasonic	Internal defect detection	intricate structure, skilled operator
Acoustic emission	Continuous monitoring , Convenience	Object-dependent, Relative measurement

Table 3-1: Comparative table for crack detection.

The main purpose of this system is correctly detecting a crack during an ongoing process. This system needs to acquire the signal in real-time to analysis with low error rates. The press panel of the automotive production line is heavy material and intricate structure. Among the crack detection methods, the acoustic emission testing is the most efficiency analytical technique for the crack detection system in automotive press panel.

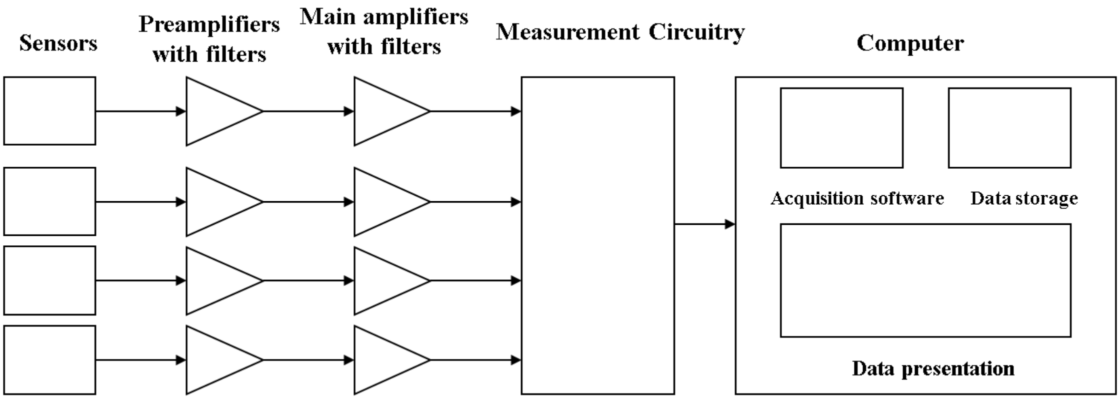


Figure 3-1: Overall Schematic of the crack detection system.

This detection system consisted of two parts: the hardware and DSP (digital signal processing) part. Among these, the hardware consisted of dual channel AE sensors, a mechanical switch, signal amplifiers, DAQ (data acquisition) board, and signal processing device. The software part consisted of the AE parameter analyzer, which used the LabView program. This program used a specialized analysis method, which used a variety of parameters such as the energy, average frequency, and duration. The AE was continuously monitored during the dome height test by using the wide band S9208 sensor of Mistras, which has a high fidelity displacement characteristic with a sampling rate of 1 MHz.

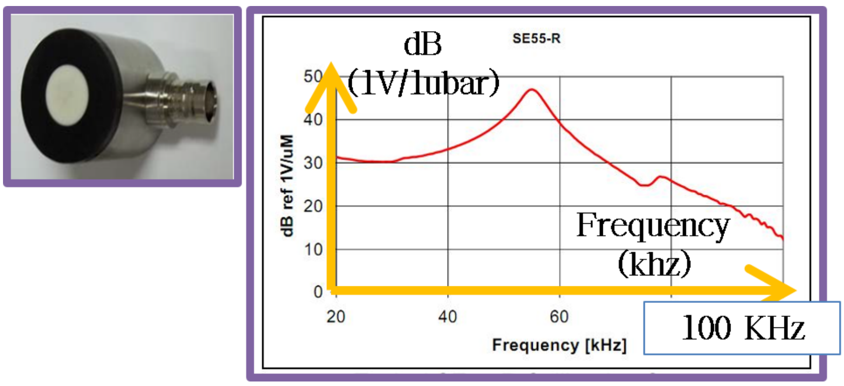


Figure 3-2: Calibration curve of SE55–R sensor of Score Dunegan.

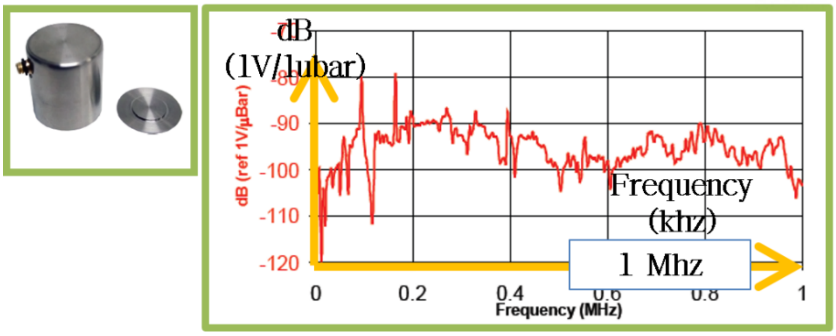


Figure 3-3: Calibration curve of S9208 sensor of Mistras.

Figure 3-4: Data acquisition device (NI 6361).

The crack occurrence tendency was measured using an NI 6361 data acquisition system from NI (National Instrument), with a sampling rate of 300 KHz and a 20dB pre–amplification. AE measurements were achieved by using a resonant Score Dunegan SE55–R sensor, which had a high sensitivity transducer well suited for testing steel structures, attached to the faces of the samples with silicon grease. The sensor was held in place with a mechanical device. The sensor case was isolated with an integral ceramic wear plate for the electrical protection of the BNC cables employed. After the installation of the transducers, a pencil lead break procedure was used to simulate AE signals in the calibration of each test.

3.2 Analytical methods

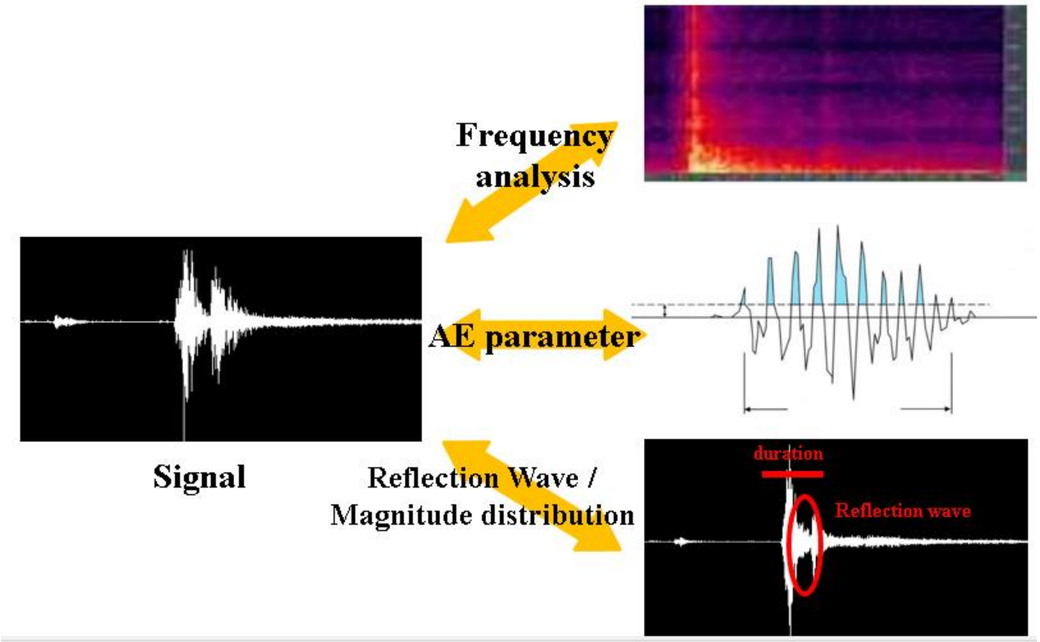


Figure 3-5: Analytical methods.

There are three method for signal processing the acquired signal. The frequency analysis, the AE parameter and reflection wave / magnitude distribution analytical method. In the frequency analysis, the wavelet (WT) transform is used for finding the special frequency of the crack in automotive production line. In time domain, acquired signal is analyzed by special parameters which named AE parameter. Finally, the raw data is analyzed by using reflection wave and magnitude distribution.

3.2.1 Frequency analysis

A special frequency detection method was employed in dome height tests with different energy levels. The data were analyzed in the frequency domain using a specialized frequency analytical method such as the STFT (Short Time Fourier Transform) and wavelet. Even though there were a variety of conditions such as different energy levels, which led to different results, these were hard to distinguish. The energy levels of the cracked and normal specimens were easily distinguished. Since the frequency band of the crack occurrence was similar to the normal condition, it was difficult to conclude that it was a useful analytical method in this implementation.

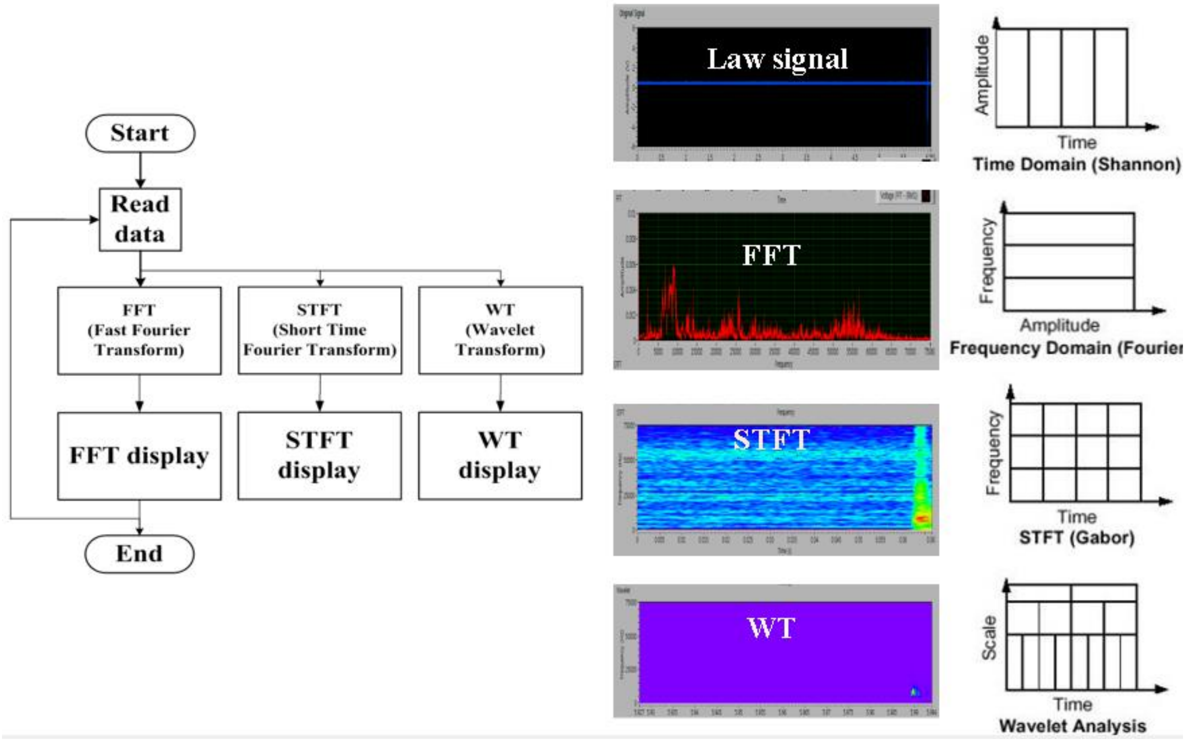


Figure 3-6: Frequency domain analysis.

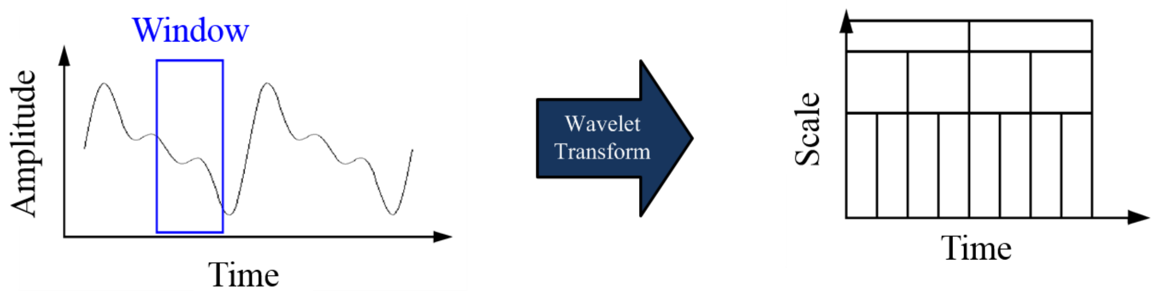


Figure 3-7: Wavelet transform.

3.2.2 AE parameters

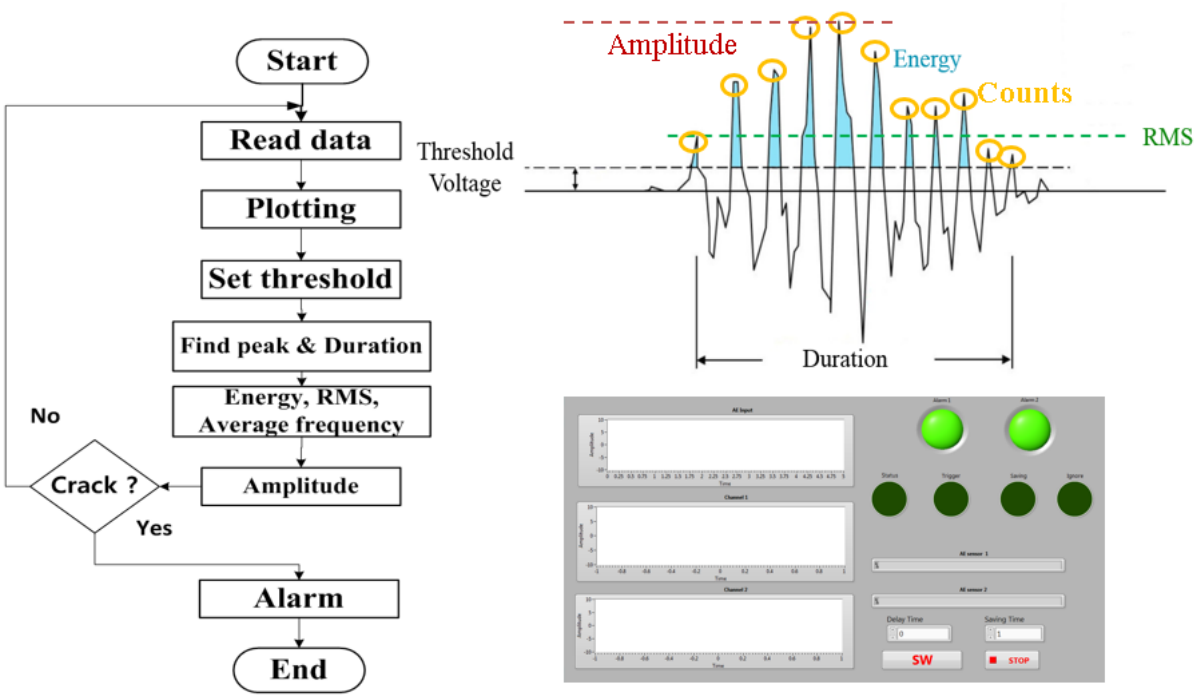


Figure 3-8: Analytic method of AE parameters.

In this test, a repeatable acoustic wave was generated. When the lead broke, there was a sudden release of stress on the surface of the sample causing an acoustic wave. We recorded five parameters for each signal, which were calculated from the waveforms (count, RMS, energy, average frequency, and duration) in combination with each parameter. These parameters were collected as the components of a vector associated with the signal from which they were derived. The parameters of a saved signal were calculated using a fixed threshold, with care taken to ensure that the threshold value was higher than the noise level. The status of a panel was determined by plotting graphs divided into plans. A signal was conventionally triggered by setting a threshold. In the case of trigger-monitoring, only the signals whose amplitudes exceeded the threshold levels were recognized as AE signals. In this measurement, the waveforms were normally employed for evaluating the AE characteristics. These were the counts, RMS (Root Mean Square), energy, average frequency, and duration.

3.2.3 Analyzing the raw data signal

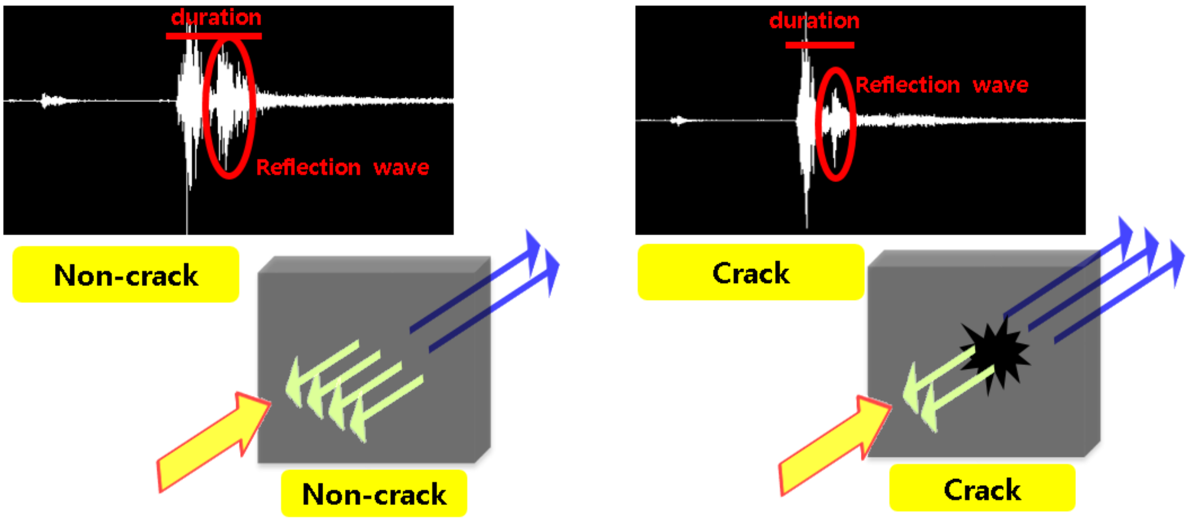


Figure 3-9: Reflection wave.

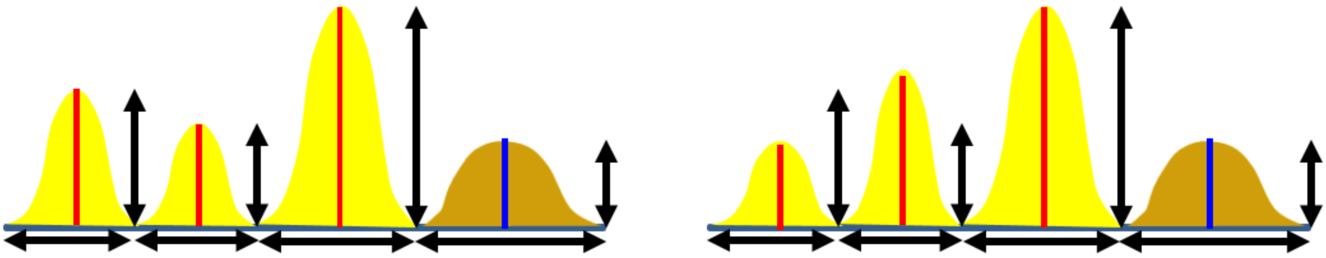


Figure 3-10: Magnitude distribution.

As shown in the figure, the raw data also have the critical information about crack detection. In this system, the reflection wave and magnitude distribution methods are employed in analytical method. In common sense, the reflected signal from the cracked panel don't have much reflection wave due to the penetrated wave. Meanwhile, the magnitude distribution represents that both cracked and non-cracked panel signal have specific patterns, respectively.

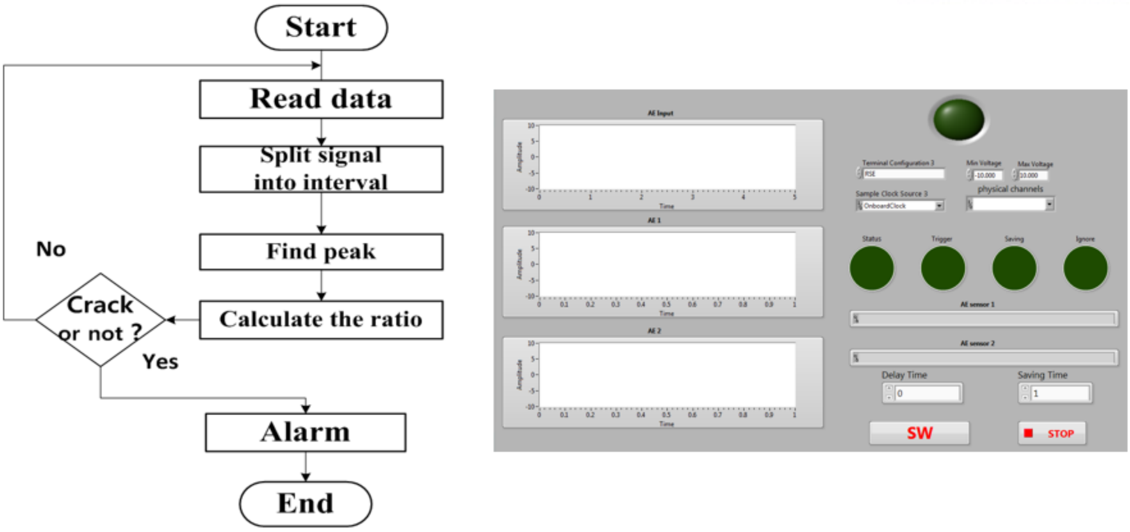


Figure 3-11: Developed program for analyzing the raw data signal.

Chapter IV

System performance

4.1 Experimental test results in laboratory

Figure 4-1: Experimental test results in laboratory.

Test specimens are subjected to a tensile impact loading by means of a pendulum. The specimen is then clamped to the crosshead and placed into the pendulum. The pendulum is released and allowed to strike the anvil breaking the specimen. The SGAFC-490DP which is dual-phase steel type with 85.6 ksi minimum tensile strength used as specimen. By using the same metal, SGAFC–490DP, for the measurements, these tests could provide predictability for the automotive press panel crack occurrence.

Figure 4-2: SGAFC-490DP.

4.1.1 Natural frequency measurement

Natural frequencies occur on all mechanical systems. In most cases they are not a problem. However, if there is an exciting force that has a frequency near the natural frequency, the vibration response will be amplified as much as 100 times what it would be without the natural frequency. When this occurs, it is known as resonance. Resonances are rarely a good thing, and will often contribute to cracking in piping or other machine components. One the best tools for identifying and correcting resonances is impact testing. This is a fairly easy technique that can be as simple as bumping the machine with your hand (small machines, of course) or with large blocks of wood. We often use instrumented force hammers to load structures with known forces and record the vibration response. The tensile testing and Limiting Dome Height (LDH) test were employed to find the natural frequency.

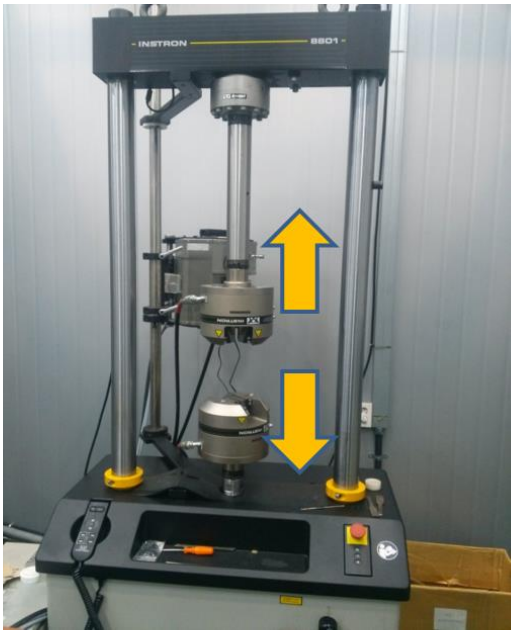


Figure 4-3: Tensile testing.

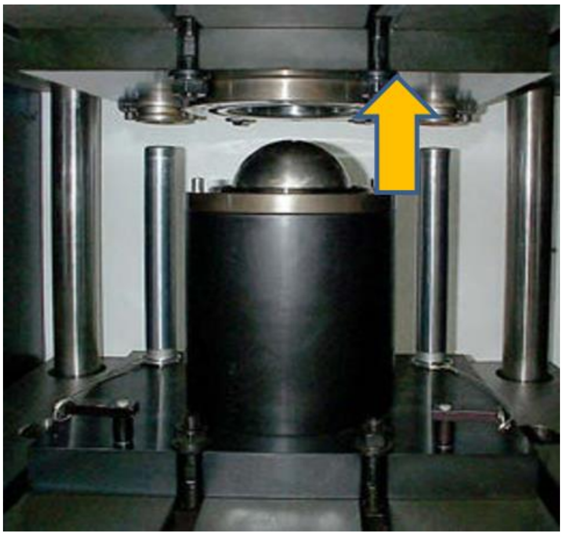


Figure 4-4: Limiting Dome Height (LDH) test.

The tensile testing is a detecting method which verify the characteristic of materials. For detecting the resonant frequency of the crack signal of the automotive press panel, it could do with investigation the special frequency. According to this analytical result, the tensile test is employed to this detection system. The Limiting Dome Height (LDH) test is also employed for above-mentioned reasons.

4.1.1.1 Frequency domain analysis

A method is presented in which fracture mechanics is introduced into finite element analysis by means of a model where stresses are assumed to act across a crack as long as it is narrowly opened. This assumption may be regarded as a way of expressing the energy absorption in the energy balance approach, but it is also in agreement with results of tension tests. As a demonstration the method has been applied to the bending of an unreinforced beam, which has led to an explanation of the difference between bending strength and tensile strength, and of the variation in bending strength with beam depth. Considering the specification of the sensor, this method was hard to detect the special frequency due to experiment environment and resonant type sensor’s characteristic. This system also employed the spectral density estimation for analyzing the data in frequency domain, however, the result of this analytical method is also vogue and not suitable for this crack detection system.

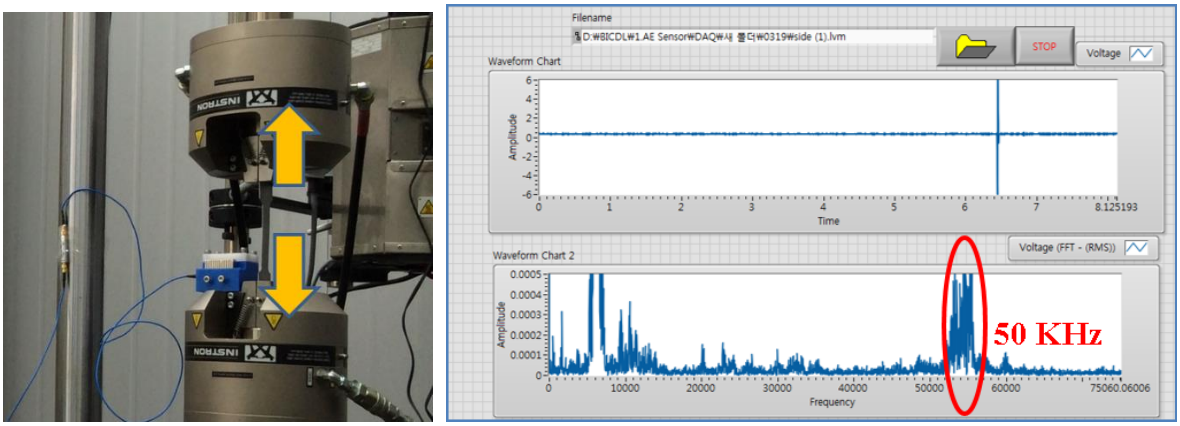


Figure 4-5: Frequency analysis.

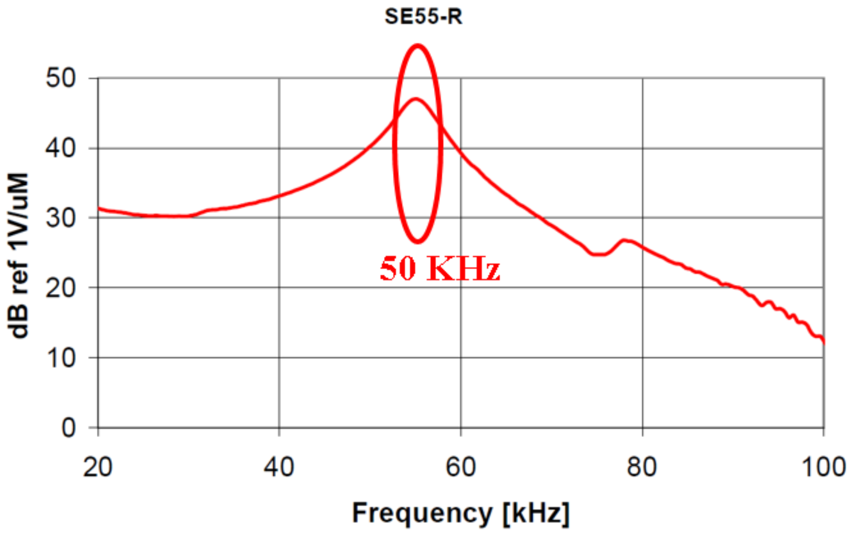


Figure 4-6: Specifications of AE sensor (SE 55-R).

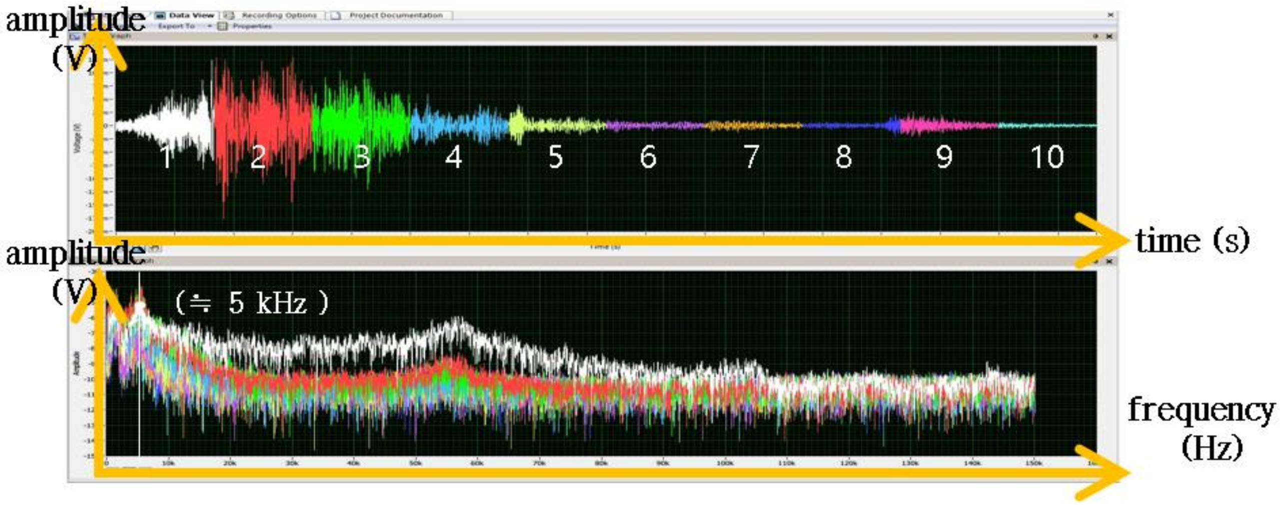


Figure 4-7: Spectral density estimation.

4.1.1.2 Wavelet analysis

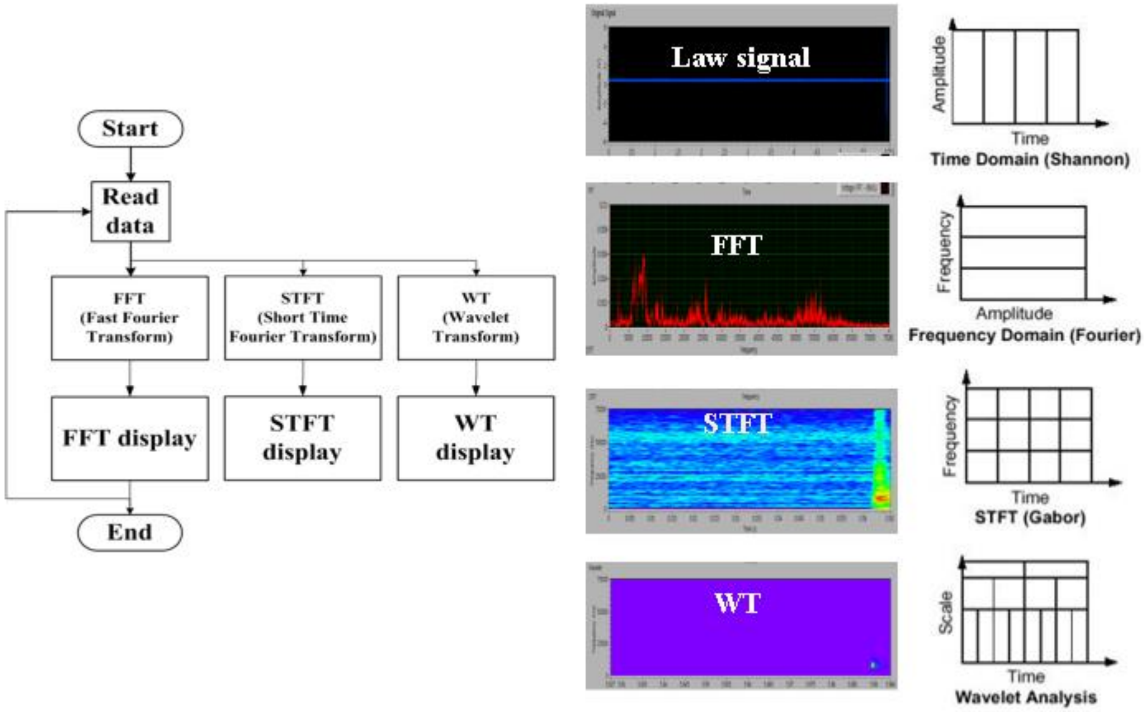


Figure 4-8: Wavelet analysis.

There were various approaches to implement the detection system for an automotive press panel. A special frequency detection method was employed in dome height tests with different energy levels. The data were analyzed in the frequency domain using a specialized frequency analytical method such as the STFT (Short Time Fourier Transform) and wavelet transform.

Even though there were a variety of conditions such as different energy levels, which led to different results, these were hard to distinguish because they only appeared graphically. The energy levels of the cracked and normal specimens were easily distinguished. Since the frequency band of the crack occurrence was similar to the normal condition, it was difficult to conclude that it was a useful analytical method in this implementation. Since the result of wavelet was expressed by brightness in the LabVIEW, this method also was hard to detect the special frequency.

4.1.1.3 Limiting Dome Height (LDH) test

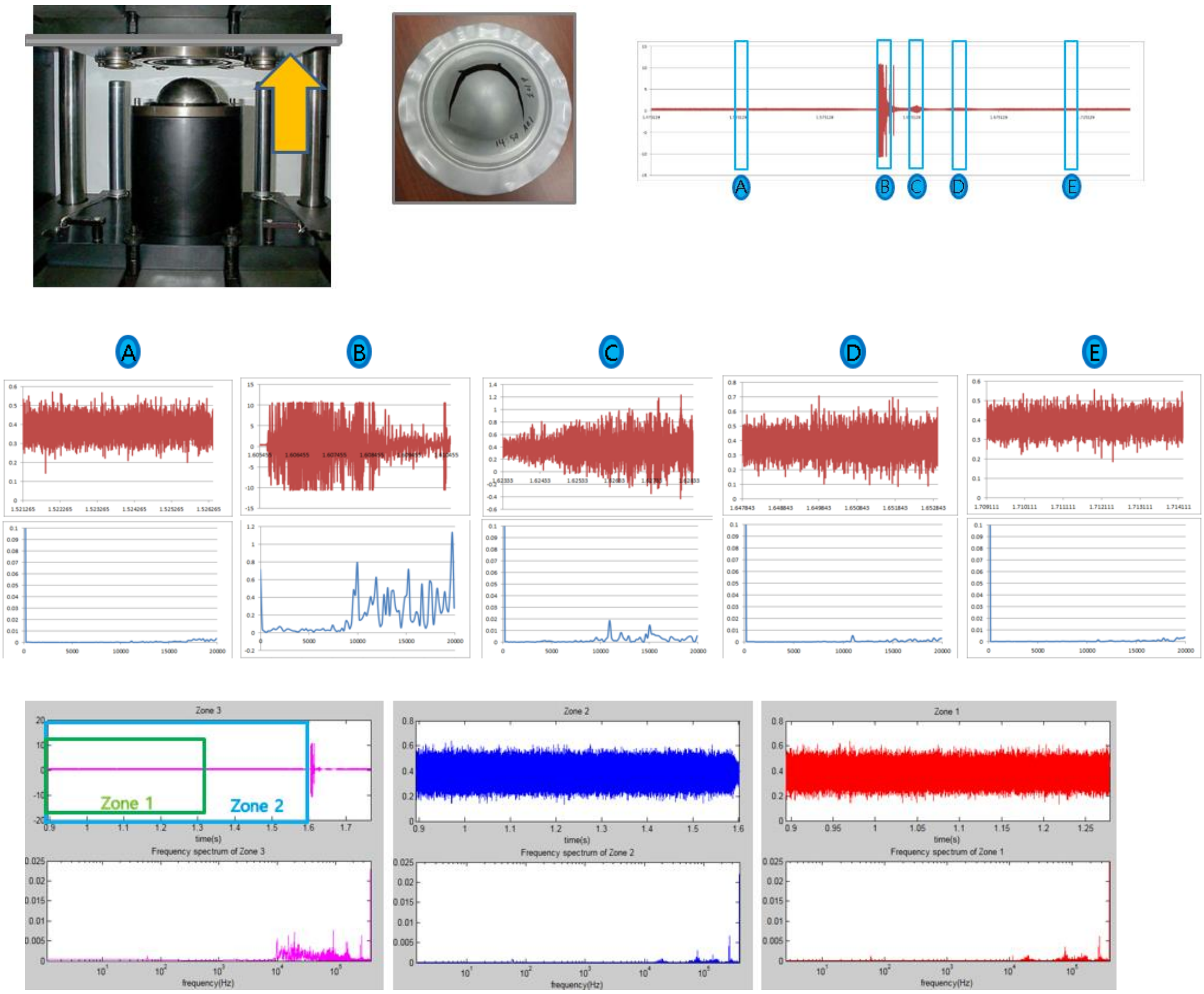


Figure 4-9: Segment analysis method.

In this test, rectangular blanks of varying widths are clamped firmly in the longer direction and stretched over a hemispherical punch, thereby varying the transverse constraint to control the amount of lateral drawing-in. Thus, the minor strain in the failure region can be changed from a positive state to a negative state. The height of the dome at a maximum load (near failure) is used as a measure of stretch ability. The segment analysis method was employed to investigate the natural frequency of the crack. However, the results from this method also was very inefficient.

4.1.2 Tensile impact test

A tensile impact test was employed to create conditions that approximated an actual factory line as closely as possible. All the monotonic tests were performed using the CEAST 9350 Drop tower Impact Systems of Instron. Each test was repeated 100 times. The tests used 80 J of falling energy. Portions of the specimen gage length were cut and polished. The CeastVIEW program of Instron was used to analyze the damage in the specimens. Figure shows our experimental environment. The amount of energy per unit area required to break a specimen under tensile impact. This test is used for materials that are either too flexible or too thin to be tested.

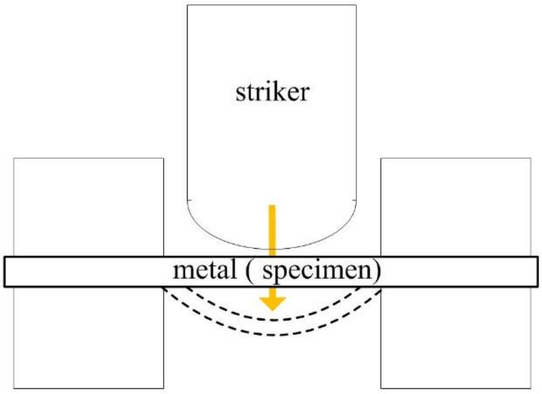


Figure 4-10: Tensile impact test.

The CEAST 9350 drop tower high velocity impact tester, supplied by Instron, is used to deliver high impact energies. The test is performed by dropping a 12.7 mm diameter hemispherical striker carrying a total weight of 14.93 kg on the composite specimens and investigating the dynamic response. The initial velocities for the tests were 2.85 m/s and drop heights were 203.9 mm with 85J energy are applied to the composites. The testing system is capable of measuring the time history with preamplifier for analysis using the data acquisition. The following responses are then calculated through the signal processor by using LabView which used in the monitoring and analysis of measured signals from tensile impact test. On-line displays of time domain of the signal provide a user-friendly data acquisition interface. PC based data acquisition (DAQ) systems in measurement and analysis is gaining importance in industry and research organizations as this can be used for teaching, research and product development due to its flexibility of using virtual instrumentation technologies.

To use digital signal processing techniques, the analog sensing signal must be converted into its digital representation. In practice, this is implemented by using an analog-todigital (AD) converter. One of the most important parameters for processing analog signals is the sampling rate. The sampling rate determines how often an analog-todigital (AD) conversion takes place. According to the Nyquist theorem, to avoid aliasing the sampling rate must be greater than twice the maximum frequency component in the acquired signal. The experimental setup is shown in the figure. The measured data are recorded and analysis using the same data acquisition card (NI PCIe-6361) at a 300 kHz sampling frequency. The prototype crack detector in tensile impact test is proposed in order to develop the crack detection system in automotive press line. The block diagram is constructed by wiring together objects that receive data from the testing machine, convert the analog signal to digital value through preamplifier and data acquisition, and perform specific functions such as parameter calculation in signal processor. The measured data is calculated by using LabView, which is its graphical source code.

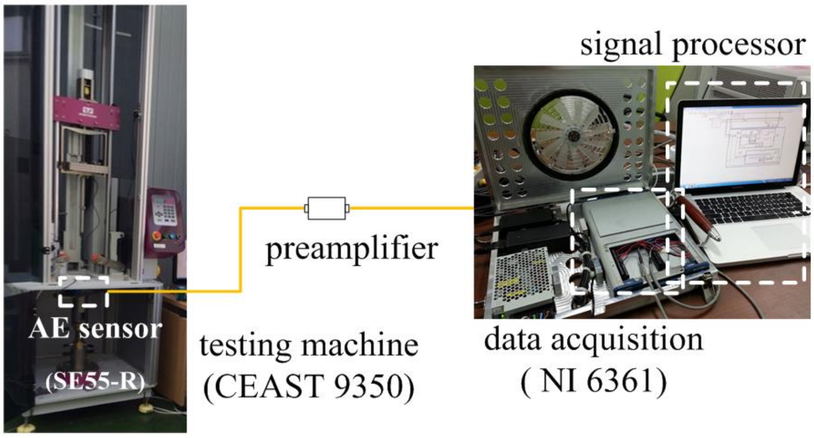


Figure 4-11: Schematic illustration of test system.

Figure 4-12: Three types of specimens: non-crack (the left), slight crack (the center), crack (the right).

Figure shows the optical specimen repeat result ruptured by tensile test. As can be seen in the figure, the loading impacts converged into a “non-crack” or “crack”. The “slight crack” which means an intermediate state between “non-crack” and “crack” also appeared at the same experiment environment. This random result implies that impact tests conducted at tipping point where is then very easy to distinguish crack growth characteristics from others. The aim of this test is to verify the crack detection system on the response of the impacted automotive metal specimens with similar environment of the press line.

4.1.2.1 One-dimensional analysis

The red circle represent crack while the blue one represent non-cracked specimens. It can be noticed that the striker did not penetrate all composite specimens when energy of 85 J was applied. Three different measurement results are examined; non-crack, slight crack and crack in this critical point. The analysis was conducted by plotting the calculated data using the Microsoft Excel program. The deformation and rupture of materials are often attributed to different mechanisms, each of which emit certain acoustic emission signals. This signals that the transducers receive during the entire failure process contain information on all of the various failure mechanisms of concrete, which overlap.

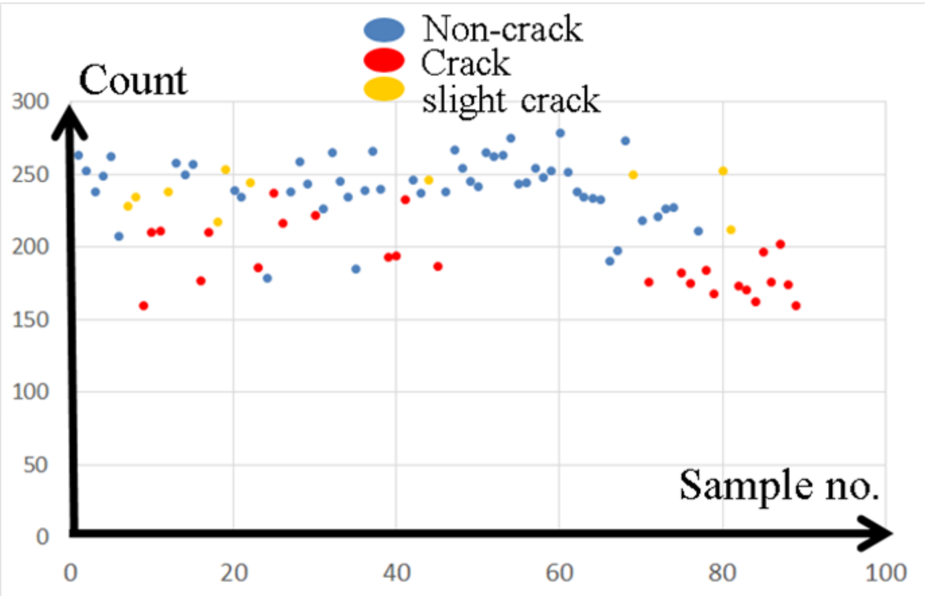


Figure 4-13: Analysis of experimental results with count.

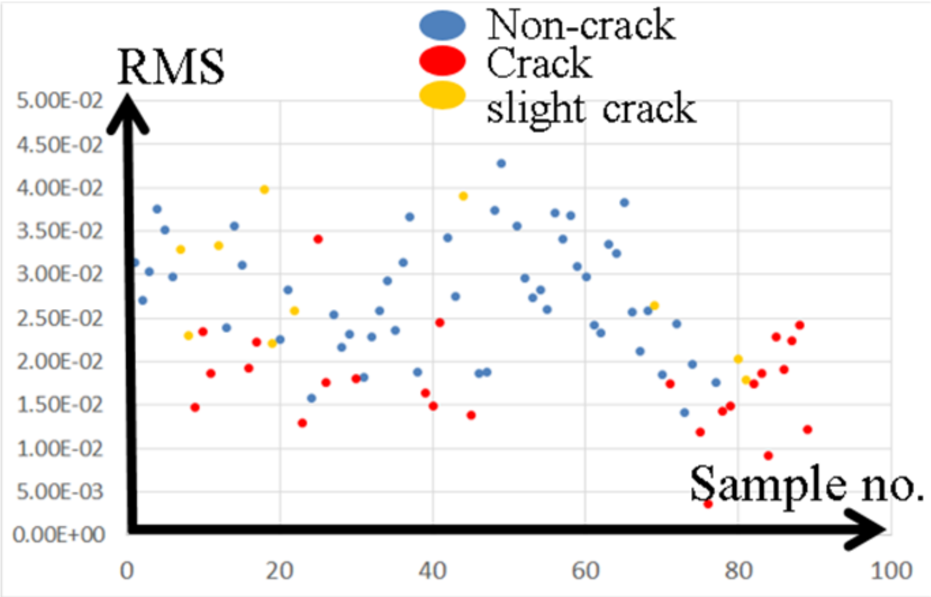


Figure 4-14: Analysis of experimental results with RMS.

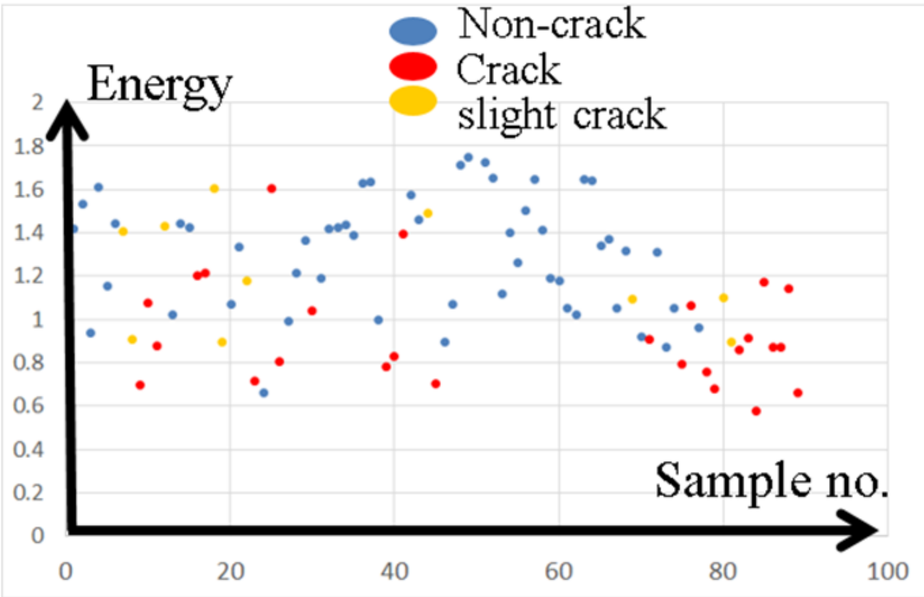


Figure 4-15: Analysis of experimental results with energy.

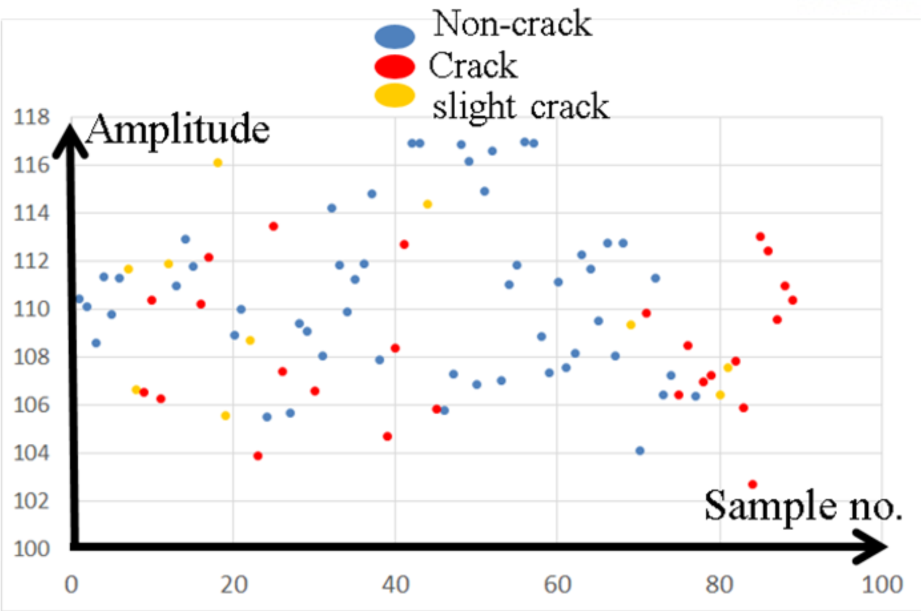


Figure 4-16: Analysis of experimental results with amplitude.

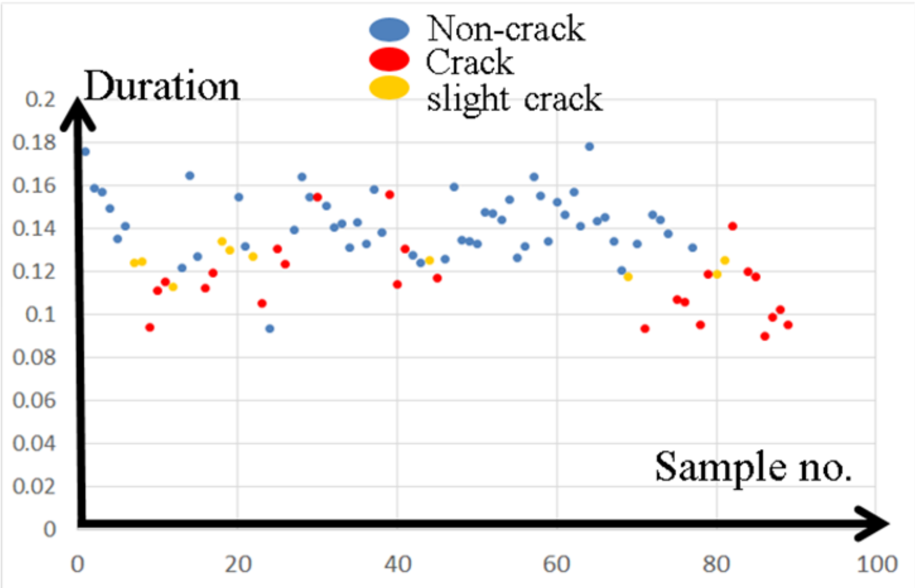


Figure 4-17: Analysis of experimental results with duration.

Figure shows examples for the time history during the impact test with different acoustic emission parameter. In order to isolate the measured signal associated with each of the different failure mechanisms, a method was proposed according to the following hypotheses: (1) According to the impact test characteristic, a necessary condition for the existence of the crack is the lower the parameter values; (2) signal activities associated with the same failure mechanism have the same characteristics. When a certain signal was measured, each graph were plotted: (a) plot of counts versus number of samples; (b) plot of root mean square (RMS) value versus number of samples; (c) plot of energy versus number of samples; (d) plot of amplitude versus number of samples; (e) plot of duration versus number of samples. Based on the above principle, different singular acoustic emission parameter occurring during the deformation and rupture of concrete cannot be distinguished.

4.1.2.2 Two-dimensional analysis

One of the crucial parameters which are influenced by the mode of crack according to the above discussion is the duration, which is defined by the ratio of threshold crossings over the duration of the signal and is measured in kHz. It is one estimate of the basic frequency content of the waveform. It is reasonable to suggest that the duration in the acoustic waveform is proportional to the energy of the associated deformation and is presented in dimensionless form. Each singular parameters have been used to characterize the cracking mode in laboratory conditions in accelerated corrosion experiments. A more accurate solution can be obtained in two-dimensional analysis by combining each independent parameter. In this part, the above method are examined; the specimen size is quite small in order to exclude significant accumulation of scattering effects, as would occur in an actual size structure of several meters. In every case the position of the sensors was fixed for all specimens and therefore, any change in the behavior during the fracture experiment is restricted to the result. In the test, the same conditions include impact energy and specimens with same thickness, shapes and coatings of approximately 100 specimens is conducted. When a certain signal was measured, each graph were plotted: (a) plot of counts versus duration; (b) plot of RMS versus duration; (c) plot of energy versus duration; (d) plot of amplitude versus duration. At the same time, the shapes and the characteristics of the three results were compared in each graph. Based on the above principle, each measurement result occurring during the deformation can be separated with a low error rate. When a certain signal was measured, each graph were plotted: (a) plot of counts versus duration; (b) plot of RMS versus duration; (c) plot of energy versus duration; (d) plot of amplitude versus duration. At the same time, the shapes and the characteristics of the three results were compared in each graph. Based on the above principle, each measurement result occurring during the deformation can be separated with a low error rate. Based on this result, this method can forecast the tendency of crack occurrences in automotive production line.

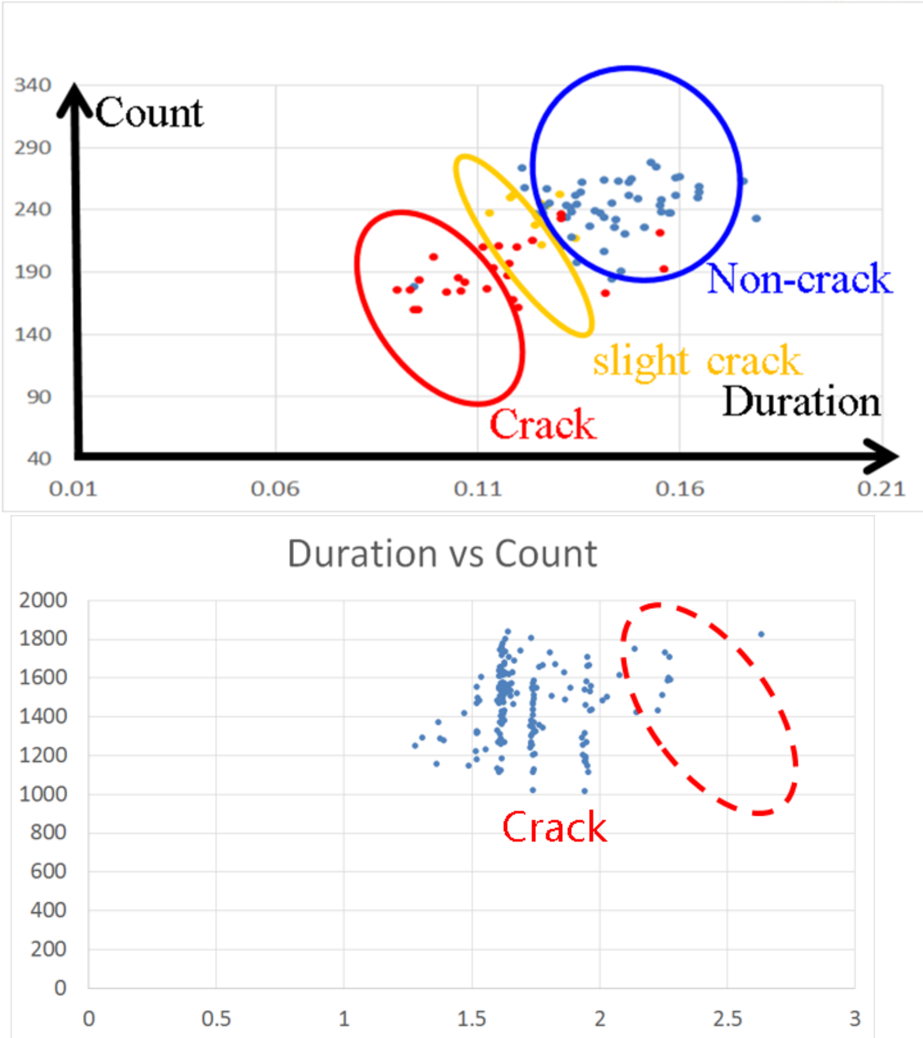
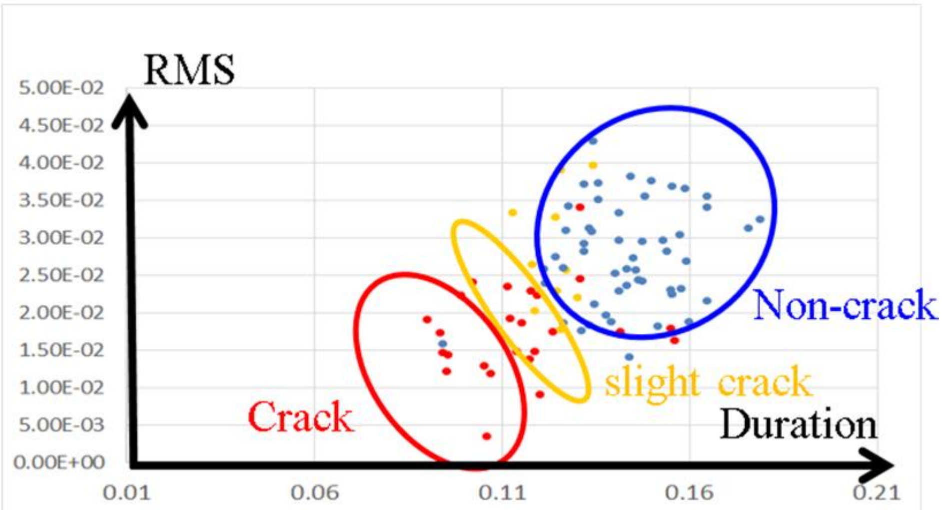


Figure 4-18: Two-dimensional analysis using count-duration parameter.



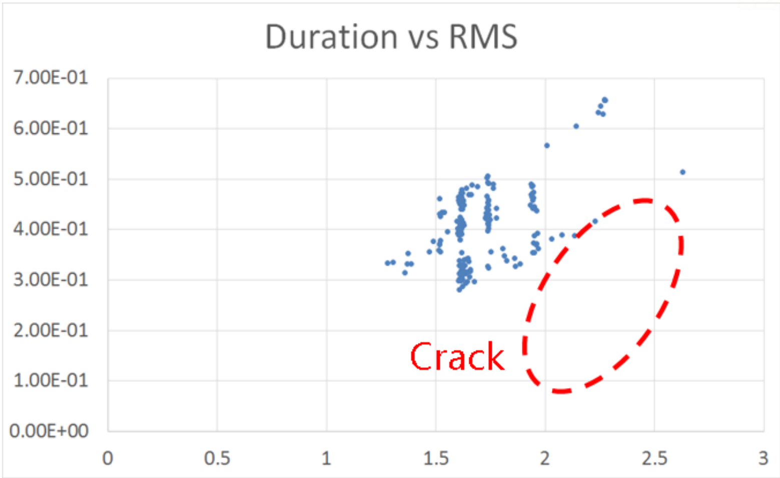


Figure 4-19: Two-dimensional analysis using RMS-duration parameter.

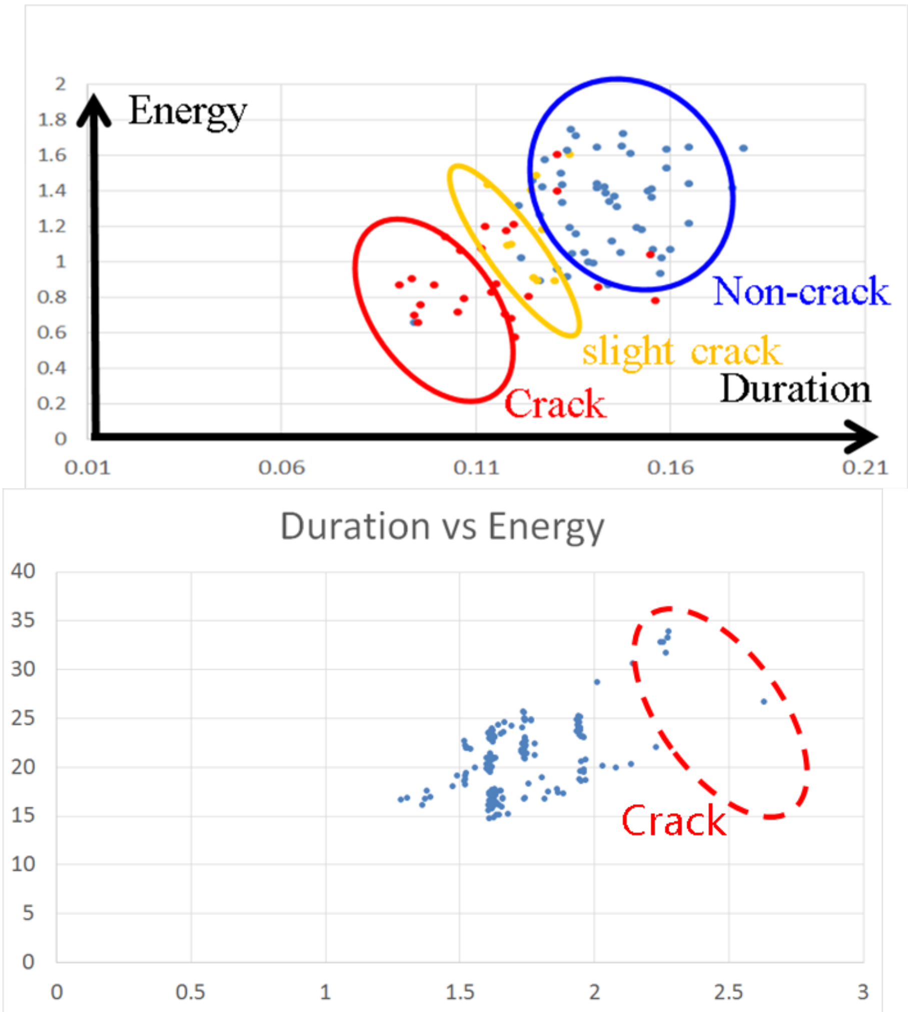


Figure 4-20: Two-dimensional analysis using energy-duration parameter.

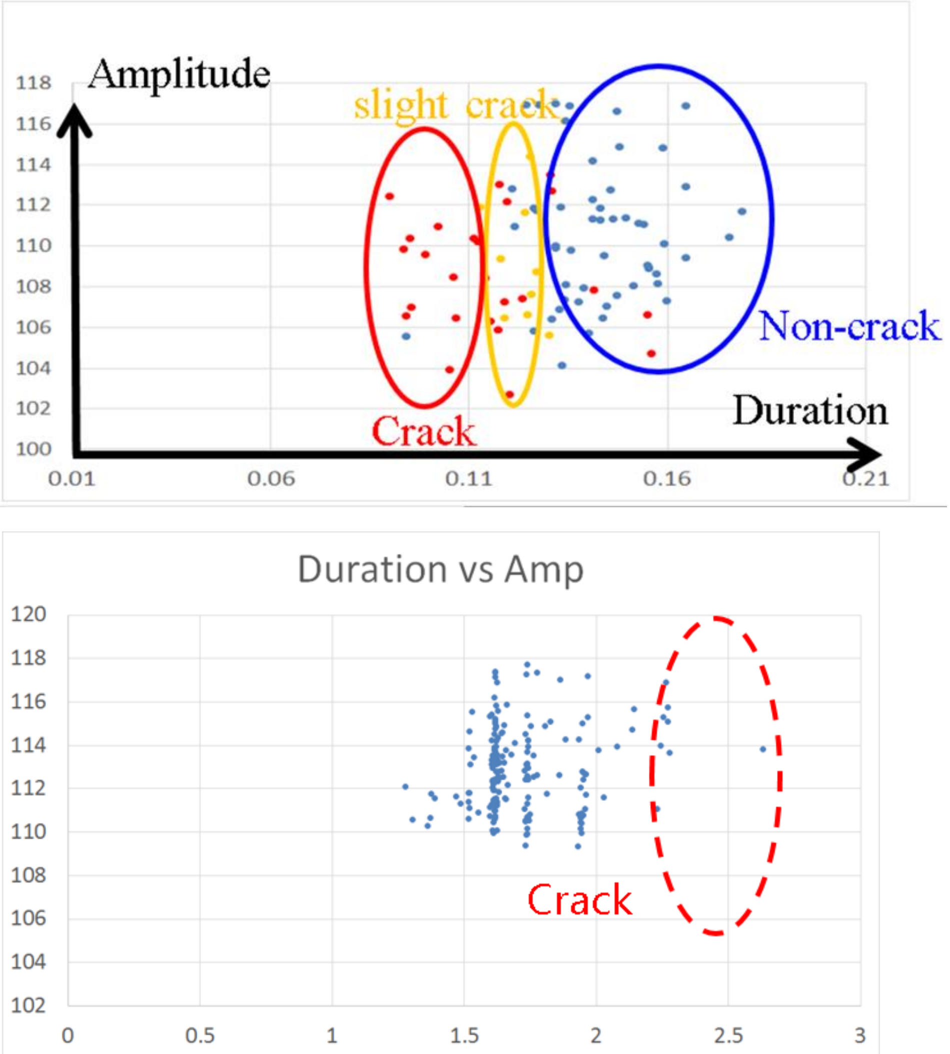


Figure 4-21: Two-dimensional analysis using amplitude-duration parameter.

Table shows the result of tensile impact test. The total number of non-cracks, slight crack, and crack are 64, 10 and 26, respectively. The error rate is defined as a component ratio that the proportion of the total for each grouping condition. For example, 4 crack signals in non-crack grouping condition indicate the 15.38 % accuracy.

Parameter	Grouping [n]			Error rate [%]
	Crack	slight Crack	Non-Crack	
Count / Duration	19	3	4	15.38
RMS / Duration	15	7	4	15.38
Energy / Duration	18	5	3	11.54
Amplitude / Duration	19	5	2	7.69

Table 4-1: Measurement result of tensile impact test.

The analysis results showed a distinct difference between crack and others. Since the resulting accuracy could be changed according to the measurement environment, the duration parameter was the most useful parameter to be verified in this measurement. By using this analytic technique, the data can be distinguished between normal and crack occurrence situations with a low error rate.

In this chapter, the proposed technique was successfully demonstrated in tensile impact test. The duration is the primary filter parameter in acoustic emission analysis. Acoustic emission techniques with duration versus counts, RMS, energy and amplitude were plotted to verify the detection system. Based on the experiments, the acoustic emission signal parameters for crack detection involved in tensile impact test were obtained test

4.2 Experimental test results in automotive production line

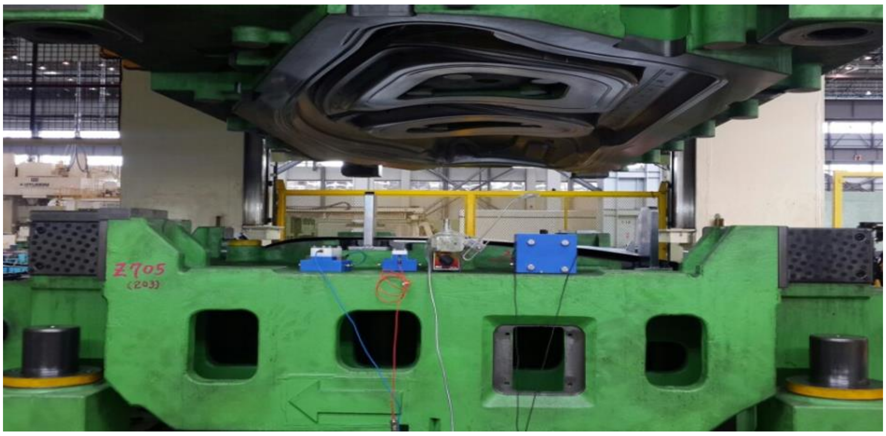


Figure 4-22: Automotive production line.

In this test, a repeatable acoustic wave was generated. When the lead broke, there was a sudden release of stress on the surface of the sample causing an acoustic wave. The AE recorded by five parameters for each signal, which were calculated from the waveforms – count, RMS, energy, average frequency, and Duration – and combinations with each other. These parameters were collected as the components of a vector associated with the signal from which they were derived. The parameters of a saved signal were calculated using a fixed threshold, with care taken to ensure that the threshold value was higher than the noise level. The status of a panel was determined by plotting graphs divided into plans. A signal was conventionally triggered by setting a threshold. In the case of trigger monitoring, only the signals whose amplitudes exceeded the threshold levels were recognized as AE signals. In this measurement, the waveforms were normally employed for evaluating the AE characteristics. These were the counts, RMS (Root Mean Square), energy, average frequency, and duration.

The required parameters is extracted through the measurement. Based on this, data acquisition was conducted in a real automotive press line with gauge ability. The measurements were conducted using microphone sensor, which allowed the system to receive a signal, not only in the AE frequency band (20~150 kHz), but also in the audible band. With operating temperature is -40˚C ~ +85˚C, a mechanical switch was used to receive a signal of a fixed receive period from the panel. In the press line, the analyzing needs to 7 seconds with 120 W of power consumption.

4.2.1 Test Environment

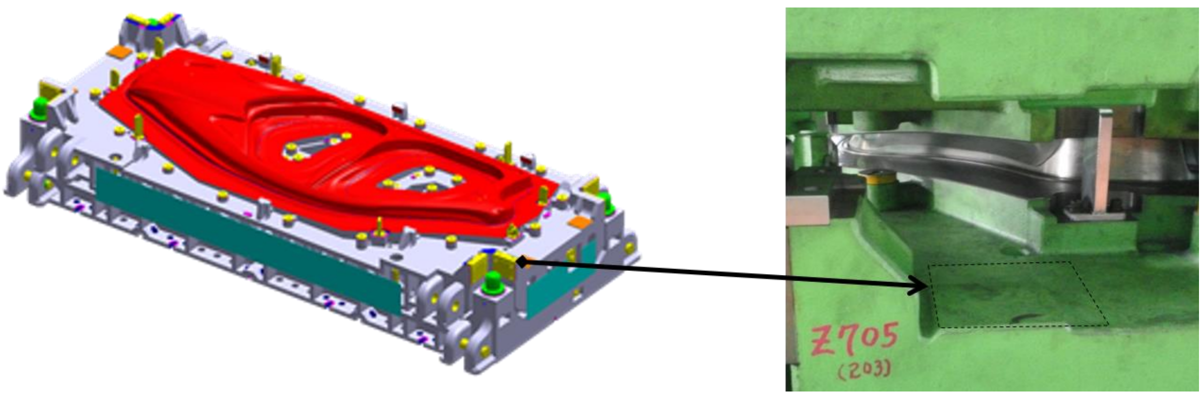


Figure 4-23: Test Environment.

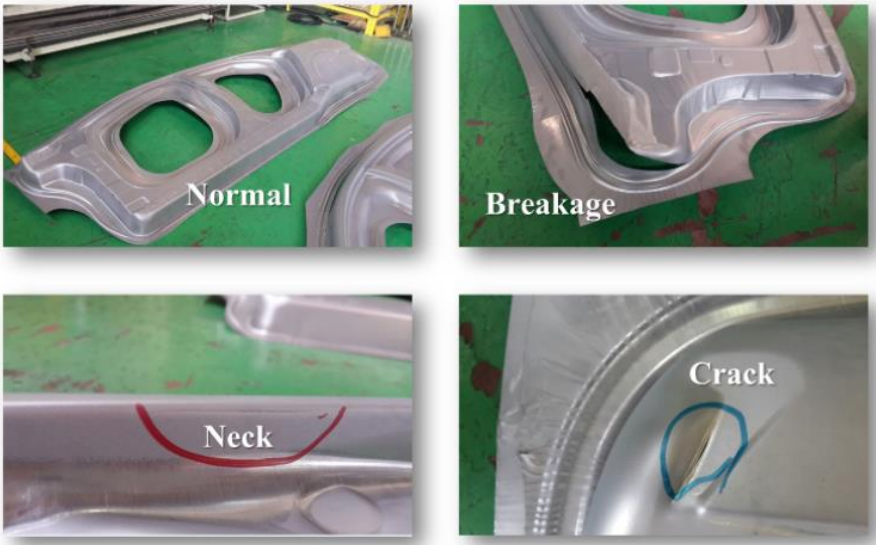


Figure 4-24: Status of crack occurrences.

The panel number from one to sixty is measured to verify our processing system in real time acquisition. Since the real crack occurred when the designed condition changed randomly, there were two variables, the pressure and friction force. According to this test, the crack occurred when a frictional force existed in the press panel. Meanwhile, no crack occurred under the same condition for test number 65 for unknown reasons. Therefore, there was a need to analyze the difference in the characteristics of the 65th panel in comparison with the other one, in which a crack occurred. The duration parameter was used for this analysis by applying the same method as used in a dome height test for comparison. As shown in the figure, the analytic technique of the duration could distinguish the 65th panel from the other one. In the meantime, the combination technique of two parameters was employed to obtain a more accurate analysis. Figure shows one of the combinations, where the horizontal axis represents the duration and the vertical axis indicates the energy of the press panel. In this figure, the segregation between a crack and non–crack is clearer than in the previous analytical approach. Furthermore, the other duration–mixing methods such as combining the average RMS or frequency also produced valid results, which showed a decided difference between the normal and cracked panels under the same conditions. This result shows the potential of an analytical technique using AE parameters applied to an automotive press panel crack detection system. It showed the potential use in a crack detection method.

Sample No.	Pressure (tons)	Frictional force	Final Status
1 ~ 60	170	–	Unconfirmed
61	240		Normal
62		Occurrence (Used sandpaper)	Breakage
63	170		Crack
64			
65			Normal

Table 4-2: Measurement result of automotive press line test.

4.2.2 AE parameters

4.2.2.1 One-dimensional analysis

The duration parameter was used for this analysis by applying the same method as used in the laboratory simulation for comparison. As shown in the figure, the analytic technique of the duration could distinguish the 65th panel from the other one.

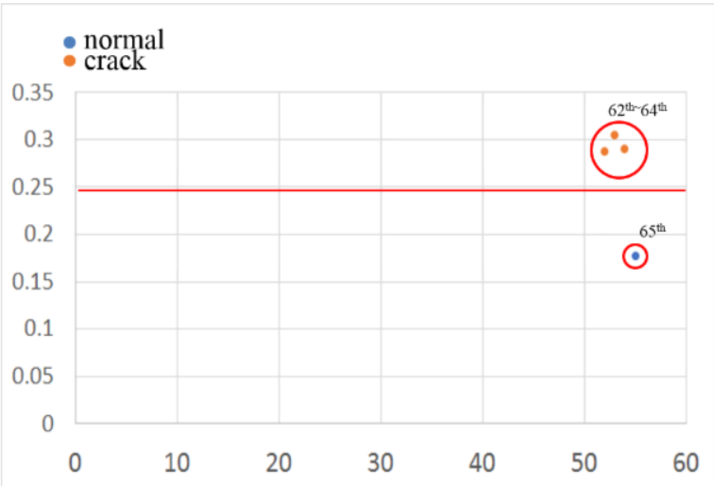


Figure 4-25: Analysis of press line results with duration parameter in press line test.

4.2.2.2 Two -dimensional analysis

In the meantime, the combination technique of two parameters was employed to obtain a more accurate analysis. Figure shows one of the combinations, where the horizontal axis represents the duration and the vertical axis indicates the energy of the press panel. In this figure, the segregation between a crack and non-crack is clearer than in the previous analytical approach. Furthermore, the other duration-mixing methods such as combining the average RMS or frequency also produced valid results, which showed a decided difference between the normal and cracked panels under the same conditions. This result shows the potential of an analytical technique using AE parameters applied to an automotive press panel crack detection system. It showed the potential use in a crack detection method.

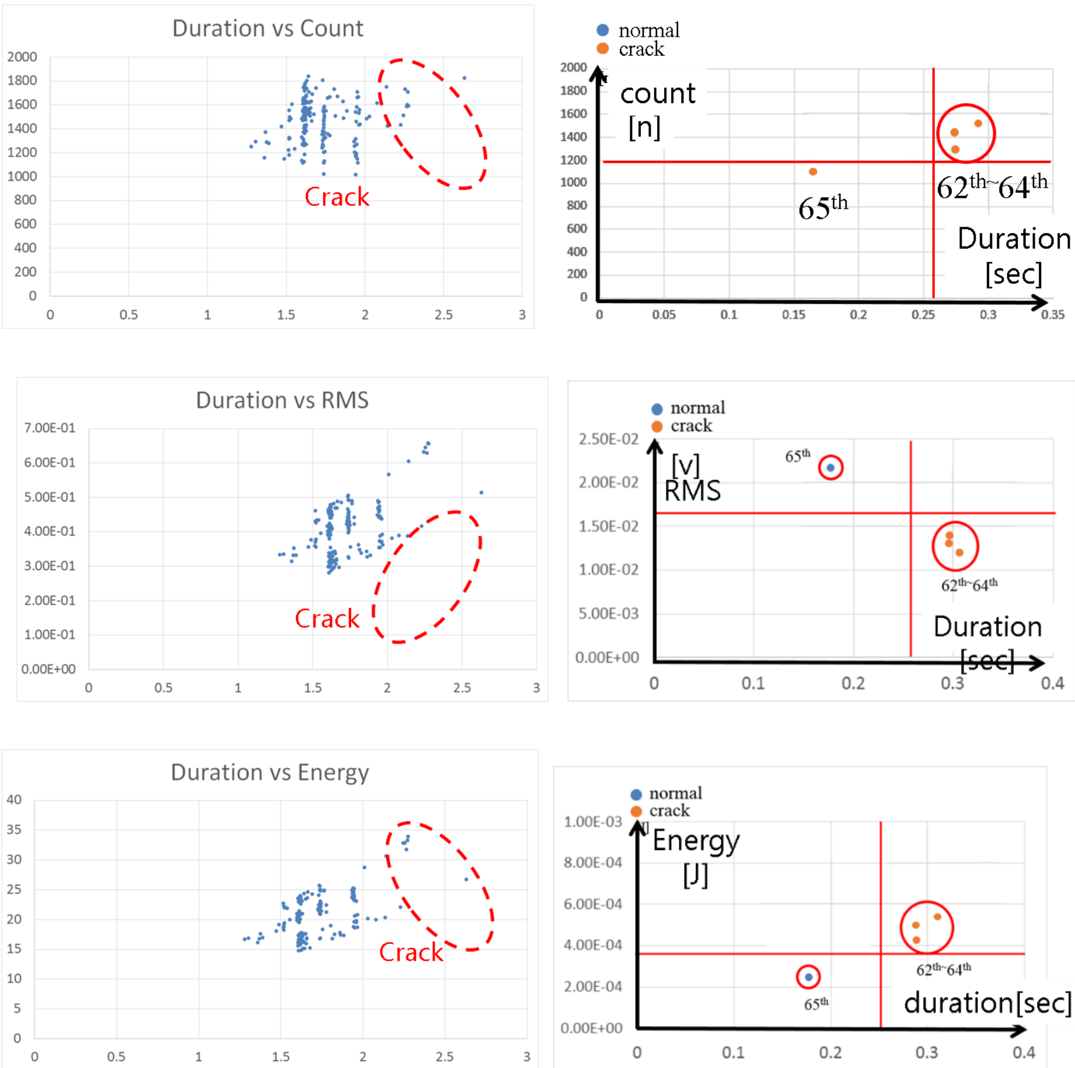


Figure 4-26: Duration analysis of press line results in combination with count (the upper), RMS (the center) and energy (the lower).

4.2.3 Analyzing the raw data signal

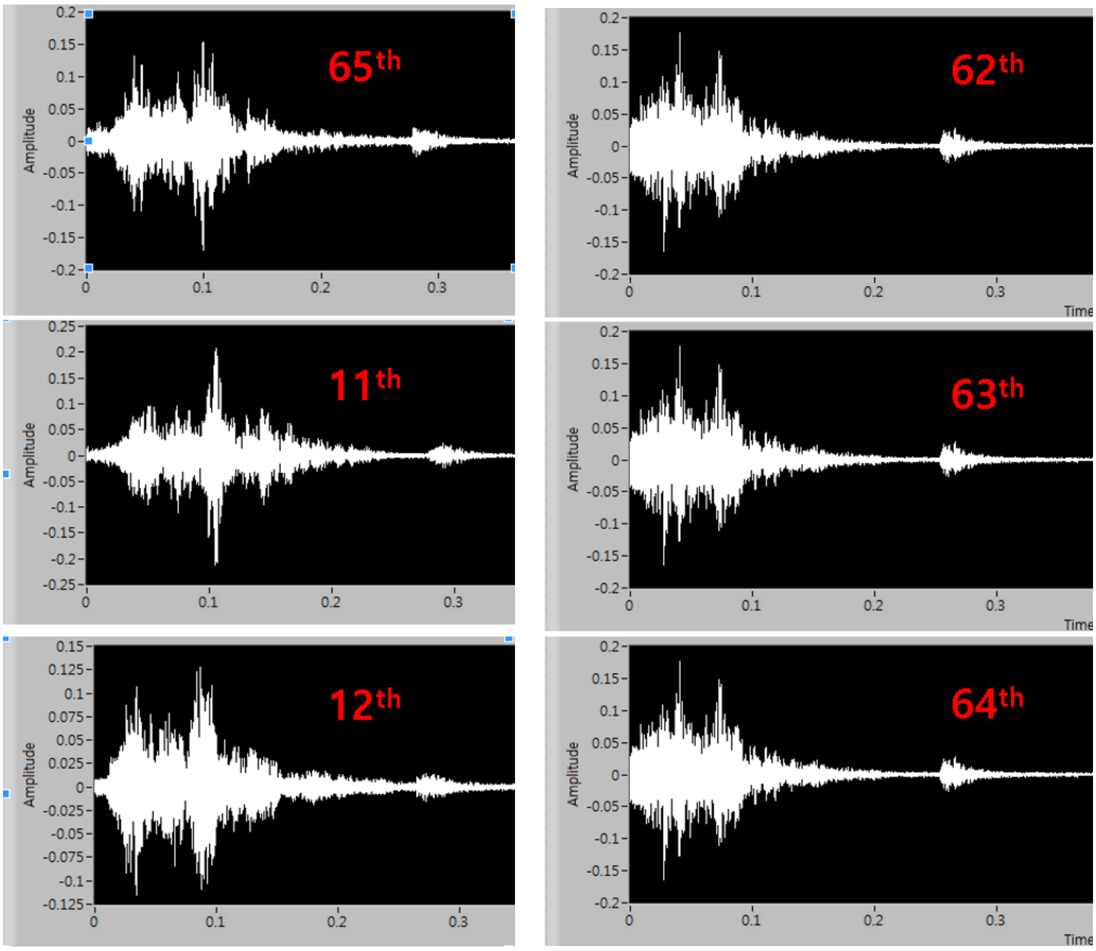


Figure 4-27: The raw data signal of non-cracked panel (the left) and cracked panel (the right).

In addition, the raw data analysis was employed to improve the reliability of the detection system. There are Reflection wave-analytic technique and method based on magnitude distribution. The raw signal from cracked panel tend to have longer reflection wave and linearly ordered magnitude shape compared to the signal from non-cracked panel.

4.3 Performance Summary

The purpose of a tensile impact test was to look for a crack occurrence pattern in comparison with the real environment of an automotive press line. By using the same metal (SGAFC–490DP) for the measurements, these tests could provide predictability for the automotive press panel crack occurrence.

Visual inspection is the common method for crack detection. However, this method has some strong limitations in accuracy and efficiency due to the structural vulnerability of a human. On the other hand, AE parameters, which consist of factors such as the count, RMS, energy, average frequency, and duration, are seen as a new alternative in this situation of their advanced structure. This chapter presents a new analysis technique by using the AE parameter analysis method which was developed to provide accurate information for operators even in real time crack detection.

In the tensile impact test, a 0.1 m × 0.1 m specimen was selected for a dome height experiment. The free fall shock machine was used to produce a crack panel by fixing the potential energy at 85 J, which was the verification threshold for the occurrence of a crack. An iron rod was used to strike the specimen, and a programmed analyzer was used. The measurement elements, including the AE sensor and preamp, were located near the specimen to get an accurate signal with noise cancelation. The signal waveform was measured using a program designed in LabView. Figure shows two kinds of specimens: the normal and cracked specimens. It can be conclude that this test was conducted under conditions that closely resembled the real environment for crack occurrence in an automotive press panel. The analysis was conducted by plotting the calculated data using the Microsoft Excel program. Since the resulting accuracy could be changed according to the measurement environment, the duration parameter was the most useful parameter to be verified in this measurement. In the figure, the horizontal axis represents the number of tests, while the vertical represents the duration. By using this analytic technique, the data can be distinguished between normal and crack occurrence situations with a low error rate.

Furthermore, the other duration–mixing methods such as combining with the energy, average RMS, and frequency also provide valid results, which show a decided difference between normal and crack panels under the same conditions. This result shows that the duration parameter is the most efficient analytical method in this test.

Chapter V

Summary & Conclusion

Figure 5-1: Promising technique for improving a crack detection system.

The costs incurred by the inspection protocols to keep a track on the damages to the automobiles has skyrocketed in recent years. In this paper, a real time crack detection system with AE method which specially produced for automotive industry is demonstrated. This paper demonstrated the first automotive press panel crack detection system that used the analytical technique of AE parameters. The nondestructive crack detection system by using parameters of AE (Acoustic Emission) signal for automotive press panels is presented. The purpose of this system is improve detection ability of crack during an ongoing process which operates seven times a minute. The system consists of two parts: the hardware and the DSP (digital signal processing) part which includes AE parameter analyzer, based on the LabVIEW program. The crack acquisition system is set to sampling rate of 300 KHz with 20dB pre–amplification. As a result, maximum received frequency range is 150 kHz according to the field test. Operating temperature is -40˚C ~ +85˚C considering the severe press factory environment with 7 seconds to analyze the data. Based on the measurement results, we can observe that the duration of the AE parameters has a higher probability of success as compared to others. It was demonstrated in an actual production line and successfully detected crack in automotive press line in real-time with 7 seconds to analyze the data. The AE signal is collected with 150 kHz of the maximum frequency in

20dB pre–amplification. This system is developed to found a promising technique in real time crack detection with contributing towards the cost reduction. The proposed system was tested and successfully demonstrated crack detection in an actual automotive production line.

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